An Ecosystem Architecture Meta-Model for Supporting Ultra-Large Scale Digital Transformations

Completed Research

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Abstract

Digital transformations all over the world intend to create or influence socio-technical ecosystems in which people and organizations are collaborating today. Many of these digitization efforts are characterized as partial or total failures, as they could not master the high complexity of a focal ecosystem, including a large number of involved actors, multi-branched collaboration processes and heterogeneous IT landscapes. In an intra-organizational context, enterprise architecture (EA) models are used to receive transparency on relations and to handle the complexity of digital transformations. This paper aims to extend the idea of EA modeling to the ecosystem level to support project managers in performing digital transformations of ultra-large scale. By conducting four case studies on digitization projects in different industries, we identified six architectural perspectives with forty stakeholder concerns on ultra-large scale digital transformations. For addressing these concerns, an ecosystem architecture meta-model is developed and demonstrated.

Keywords

Digital Transformation, Ecosystem Architecture, Enterprise Architecture, Meta-Model, Concerns

Introduction

In times of a maturing digitization around the world, organizations are moving beyond traditional industry silos and coalescing into highly collaborative networks. They are part of complex ecosystems, in which they generate new opportunities for innovation, resource sharing and value creation by interacting with their customers, suppliers and competitors. Behaving similarly to naturalistic systems (Moore 1996), these ecosystems can be defined as “evolutionary self-organizing cross-industrial systems of independent economic actors that are connected by value-added chains” (Benedict 2018). In Information Systems Research (ISR), ecosystems have become a popular research object, as digital transformations of ultra-large scale caused by innovative entrepreneurs with data-driven business models (e.g., Uber, Airbnb), new technologies (e.g., artificial intelligence, Internet of Things (IoT)) and governmental digital initiatives have raised richly networked ecosystems based on distributed actors and their interconnected information technology (IT). These ultra-large scale digital transformations can be defined as digitization projects that aim to change the behavior of a very large number of actors, have a long project duration and refer to a multitude of long-distance relations between social and technical entities in a focal ecosystem. Earlier publications focus on the business models and strategies in these ecosystems (Iansiti and Levien 2004), the relationships and economic effects of co-evolution (Clarysse et al. 2014) and the properties of different ecosystem types (Benedict 2018).

However, research shows that 83% of digital transformations are categorized as partial or total failures with two major reasons being 1) the unbalancing of ecosystems due to a missing analysis and acknowledgement of continuous influences and 2) the inadequate assessment of the magnitude of change during the progress
of transformation (Alami 2016). Consequently, approaches are needed that enable both the analysis of as-is states of an ecosystem and the transformation towards to-be states of an ecosystem (Drews and Schirmer 2014). In an intra-organizational context, the enterprise architecture management (EAM) is intended to support the analysis, design and deployment of transformation projects. By referring to enterprise architecture (EA) models that capture present and planned states of business and IT elements, transparency on intra-organizational relations can be achieved. Nevertheless, when extending the scope to an ecosystem level during ultra-large scale digital transformations, organizations are confronted with an even greater complexity (e.g., changes to the EA of multiple actors, emergence of new collaboration processes) and have the necessity to observe relevant slices of the ecosystem they are influencing. In this paper, we therefore aim to support the analysis and realization of ultra-large scale digital transformations by developing an ecosystem architecture meta-model that seeks to reduce the complexity of ecosystems into coherent layers. We build upon the idea of extending EA modeling to an ecosystem perspective, as EA meta-models have proven their value in creating transparency and supporting transformation projects in the enterprise context (Winter and Fischer 2007; Aier et al. 2008). We argue that an ecosystem architecture meta-model not only enables the derivation of concrete models that provide an understanding of specific ecosystems, but also can act as a basis for positioning an architectural thinking (Winter 2014) in ultra-large scale digital transformations to prevent failure. As architectural models are intended to address specific information needs of stakeholders (Saat et al. 2010), we conducted case studies on four digitization projects that aimed to transform different types of ecosystems and derived stakeholder concerns (Niemi 2007) as the basis for developing our ecosystem architecture meta-model. Therefore, we address the following research question: Which layers, elements and relations need to be included in an ecosystem architecture meta-model for addressing stakeholder concerns in ultra-large scale digital transformations?

The remainder of this paper is structured as follows. In the next section, we summarize related research to provide an overview of the state of the art regarding our topic. Following, we outline our research approach and briefly describe the analyzed cases. Afterwards, we present the derived stakeholder concerns and the developed meta-model. Next, we discuss our results and roughly reflect the idea of an architectural thinking in the large. Finally, the paper closes with a conclusion, an explanation of limitations and an outlook.

Related Research

Within our defined aim, we identified three streams of related research. The first stream addresses the basic concepts of EA and defines fundamental elements of EA meta-models. The second stream delimits different types of ecosystems and analyzes existing ecosystem meta-models. The third stream refers to research that aims to extend the horizon of EA beyond organizational borders and towards an ecosystem perspective.

Generally, the term architecture is defined as “the fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution” (IEEE 2011). For describing the EA, where the observed system applies to a company or authority, various EA meta-models exist in the literature that structure the artifacts of EA, their attributes and relations along logical layers. According to Winter and Fischer’s (2007) literature analysis, five EA layers build a common basis: business (e.g., strategic goals, market segments), process (e.g., business processes, organizational units, information flows), integration (e.g., enterprise services, application clusters, interfaces), software (e.g., software components, data structures) and technology (e.g., hardware and network components). Recent EA meta-models attempt to address the data-driven nature of today’s organizations by focusing on big data, security and privacy issues (Burmeister et al. 2019). EA meta-models, however, provide a common language and a template for deriving coherent instances of as-is and to-be EA models by addressing concrete stakeholder concerns, which are “interests related to the development of EA, its use and any other aspects that are important to one or more stakeholders” (Niemi 2007). By applying to these concerns, EA models support various stakeholders in receiving transparency on the complex relations between elements in their organization and in analyzing the properties of current and potential future scenarios. Thus, they play an essential role in the EAM and its major tasks of strategic planning, improving business IT alignment and realizing continuous transformation as smoothly as possible (Saat et al. 2010).

To capture the extended environment in which organizations act today, several concepts are discussed in the literature. Many of them focus on understanding the manifold forms of collaborative networks like virtual organizations, supply chains or industry clusters (Camarinha-Matos and Afsharmanesh 2008). However, ISR has been paying increasing attention to the concept of ecosystems in recent years, trying to define...
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and understand the characteristics of different ecosystem types. In ISR, the term ecosystem most often refers to business ecosystems, which are defined as “an economic community supported by a foundation of interacting organizations and individuals - the organisms of the business world” (Moore 1996). The role of the enterprise within a business ecosystem can range from a keystone to a niche player, with varying level of influence on an ecosystem’s overall health (Iansiti and Levien 2004). Typical characteristics of a business ecosystem refer to co-evolution, emergent behavior, self-organization, adaptability and decentralized governance (Drews and Schirmer 2014). Other dominant types in ISR are digital ecosystems (focus on digital objects that are shared between actors), platform ecosystems (focus on network effects by connecting actors through a platform) and service ecosystems (focus on the value co-creation and exchange of services). As there are some additional types in the literature, Benedict (2018) provides a decent overview by clarifying and systematizing the types of ecosystems used in ISR. Some ecosystem meta-models in the literature aim to capture the relations between components of an ecosystem, but focus on selected aspects due to the high complexity. Moore (1996) for instance, illustrates the stakeholders interacting in a business ecosystem and classifies them into a core business layer, an extended enterprise layer and an overarching business ecosystem layer. Other authors provide first steps towards a service ecosystem meta-model (Feltus et al. 2017) and a data ecosystem meta-model (Oliveira et al. 2018). However, these meta-models do not have their origin in the EA and do not combine elements of the actor-based EA with the ecosystem architecture. Because of their specific scope and attention to a given topic, they provide a focused lens for ex-post analysis, but give rather limited perspectives to support various types of ultra-large scale digital transformations in different ecosystem types. Clarysse et al. (2014) state that there is different logic of action in different ecosystem types and that the same actor can be involved and play different roles in each ecosystem. Therefore, a generalized ecosystem architecture meta-model should integrate essential elements of multiple ecosystem types. Although most existing research in our context focuses either on EA or on ecosystems, some publications address issues of extending the EA to an ecosystem perspective. Drews and Schirmer (2014) for instance, describe stages from EA towards an ecosystem (extended EA, collaborative network architecture, focused ecosystem architecture). With each step, the scope of the architecture increases as interfaces to more actors in an organization’s environment are considered. Additionally, they highlight the need for an ecosystem architecture meta-model as one of the main challenges during these stages and that empirically grounded “concerns need to be defined, which underline the need for this extended perspective” (Drews and Schirmer 2014). Other scholars performed a literature analysis on the applicability of TOGAF for managing network organizations (Müller et al. 2013). They concluded that the framework is well suited in areas of process and data integration, infrastructure and application integration as well as governance, but only partly covers inter-organizational challenges, as they could “not find any relevant parts of the framework which provide solutions regarding management of the inter-organizational connections of the network” (Müller et al. 2013). Having a look at EA meta-models, only a few include artifacts that are not part of the organization itself. Aier et al. (2008) propose artifacts called “interaction with customers”, “interaction with suppliers” and “market segments” to capture inter-organizational relations. In their privacy-driven EA meta-model, Burmeister et al. (2019) have included some actor artifacts to describe data flows and external data sources. However, these artifacts are looked at from an inside perspective to address intra-organizational concerns. To conclude, we 1) did not find an ecosystem architecture meta-model that considers the EA of specific actors and is able to reflect different ecosystem types. Weber and Hine (2015) even state that the bodies of knowledge on ecosystems research in general “are not well integrated, tend to be studied in isolation, and often diverge in approach depending upon the level of analysis. The focus is frequently on a single actor, feature, or platform that, while providing depth of coverage, does not adequately address holistic ecosystem complexity.” In the existing literature on extending EA to an ecosystem perspective, we 2) identified the explicit need for an ecosystem architecture meta-model that addresses empirically grounded inter-organizational stakeholder concerns and captures relevant artifacts that illustrate interconnection between actors.

Research Approach

To address the previously revealed research gap and to develop the ecosystem architecture meta-model, we followed a design science oriented research approach (Peffers et al. 2007) consisting of four steps (see Figure 1). As our intention was to integrate layers and artifacts similar to EA meta-models, but at the ecosystem level, and to address information needs in different kinds of ultra-large scale digital transformations, we draw upon a bottom-up meta-modeling approach based on stakeholder concerns according to Lagerström et al. (2009). To get additional top-down guidance, we considered Benedict’s (2018) requirements.
for ecosystem modeling, including generativity (consider unpredicted actors and technologies), co-evolution (model information flows and technology interaction), cooperative behavior (model business models and their combination by different partners), coopetition (model cooperation and competition), recombination (realize a component-oriented modeling) and self-organization (model individual goals for each actor).

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Development</th>
<th>Demonstration</th>
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<tr>
<td>1) Case studies on different types of ultra-large scale digital transformations</td>
<td>2) Translation of analysis results into exemplary stakeholder concerns</td>
<td>3) Identification of layers, artifacts and attributes and definition of their relations</td>
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<td>4) Explanation of the meta-model by horizontal and vertical slicing</td>
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**Figure 1. Research Approach**

In a first step, we conducted case studies on ultra-large scale digital transformations in different types of ecosystems. By performing expert interviews (Myers and Newman 2007) within these cases, we gained insights into the transformation-related information needs of stakeholders that were responsible for the design and execution of these projects. In a second step, we transcribed the recordings of these interviews and coded the material to identify main topics of interest concerned by the interviewees, which we in the following call architectural perspectives. We then consolidated the frequently mentioned information needs, transferred them to more concrete stakeholder concerns (Niemi 2007) and categorized them by these architectural perspectives. Third, by referring to existing EA meta-models and ecosystem meta-models we presented in the related research section, we inductively derived relevant elements and mapped them to the identified stakeholder concerns in order to develop our meta-model. In the fourth step, we seek to demonstrate the usefulness of our meta-model for analyzing and realizing ultra-large scale digital transformations by giving examples from the cases and discussing the advantages from an architectural thinking in the large.

Since our claim was to develop a generalized ecosystem architecture meta-model that could be applied to a heterogeneity of digital transformation scenarios, we conducted the four case studies in preferably diverse domains. The first case study refers to two e-government projects in Germany, namely the introduction of the German electronic identity (eID) card and the communication service De-Mail. These projects shared the same goal of improving security and efficiency of online collaboration between citizens, authorities and companies. Although these projects reached their defined goal, only 5% of all German citizens were using these solutions in 2015 (Otterbein et al. 2017). In our study, we interviewed project initiators and involved employees from the responsible German ministries as well as key partners to understand the reasons for non-adoption and to recapitulate which architectural concerns had to be answered to consider these reasons. The second case deals with the worldwide spread of healthcare apps and related digital transformations of actors (e.g., medical practices and hospitals). We analyzed the ecosystems of three healthcare apps including Vivy, MediRecords and TK-App to understand their specific socio-technical characteristics. We chose these apps as representatives, since they have a high reach, popularity and number of users in Germany (Vivy, TK-App) and Australia (MediRecords). Key questions referred to the transformation of processes in these ecosystems, the emergence of information flows between actors and the sharing and protection of personal data. The third case study accompanied an initiative for exploring the use of IoT technology in an international seaport. Our analysis focused on the architectural preparations for the rollout of IoT-driven use cases, which partly affected the ecosystem including forwarding companies and truck drivers. The fourth case study had the transformation of schools by a software development company at its core. The company successfully established a platform ecosystem for software that allows collaboration and data exchange between schools.

**Results**

In our research, we seek to introduce an architectural thinking at the ecosystem level to support the success of ultra-large scale digital transformations. The derived stakeholder concerns and the ecosystem architecture meta-model we present in the following are intended to provide a starting point for this intention.

**Derivation of Stakeholder Concerns**

Major characteristics of ultra-large scale digital transformations refer to a large number of involved actors, a long project duration and a multitude of long-distance relations between social and technical entities. An architectural meta-model that seeks to support such highly complex endeavors cannot strive to capture all these entities at a very high level of detail. While in EA meta-models the business capabilities, processes and
IT systems can be taken into account on the instance-level, an inter-organizational ecosystem perspective requires selected pathways. Thus, we categorized the key issues revealed in our case studies into six architectural perspectives (see Table 1). As we mostly interviewed project initiators or people being responsible for the success of such a transformation, we derived the concerns from the viewpoint of these stakeholders to support their decisions and comprehension of the ecosystem. We additionally distinguish between concerns that belong to the analysis (as-is) and the future design (to-be) of an ecosystem. In the following, we exemplify the architectural perspectives and selected concerns by concrete insights from our case studies.

<table>
<thead>
<tr>
<th>Architectural perspective</th>
<th>Analysis (as-is) Concern</th>
<th>Design (to-be) Concern</th>
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<tr>
<td>Identification of actor classes</td>
<td>C1.1 Which actor classes currently exist within the ecosystem?</td>
<td>C2.1 How do actor classes change during the transformation?</td>
</tr>
<tr>
<td></td>
<td>C1.2 Which functions, roles and interests do actor classes in the ecosystem have?</td>
<td>C2.2 How might functions, roles and interests of actor classes change?</td>
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<tr>
<td></td>
<td>C1.3 What types of business models exist in the focal ecosystem?</td>
<td>C2.3 Which opportunities for new business models will the transformation create?</td>
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<td></td>
<td>C1.4 Which contracts currently exist between which actor classes?</td>
<td>C2.4 Which contracts between actor classes are required for the transformation?</td>
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<tr>
<td>Transformation and collaboration of actor classes</td>
<td>C1.5 How does an abstract model of an actor class common EA look like?</td>
<td>C2.5 How does the abstract EA of an actor class change due to the transformation?</td>
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<td></td>
<td>C1.6 Which essential collaboration processes exist between which actor classes?</td>
<td>C2.6 Which collaboration processes will be created or changed by the transformation?</td>
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<td></td>
<td>C1.7 Which information systems, infrastructure components and interfaces are used for which collaboration processes?</td>
<td>C2.7 Which information systems, infrastructure components and interfaces have to be modified or newly integrated?</td>
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<td>C1.8 What are overarching domain goals focussed by actors within the ecosystem?</td>
<td>C2.8 To what extent will achieved transformation goals contribute to domain goals?</td>
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<td></td>
<td>C1.9 Which defined transformation goals do project managers aim to realize?</td>
<td>C2.9 Which transformation goals must project managers align due to external influences?</td>
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<td>C1.10 Which external influences are main drivers within the focal ecosystem?</td>
<td>C2.10 What impact will external influences likely have on the interests of actor classes?</td>
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<td></td>
<td>C1.11 Which digital trends are relevant to the ecosystem and its actor classes?</td>
<td>C2.11 How do actor classes adopt new digital trends and change their EA?</td>
</tr>
<tr>
<td>Legislation and certification</td>
<td>C1.12 Which regulations are of major relevance for the involved actor classes?</td>
<td>C2.12 What are potential effects of changing regulations on the transformation?</td>
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<td></td>
<td>C1.13 Which IT artifacts have to comply with specific certification requirements?</td>
<td>C2.13 Which IT artifacts created or changed by the transformation require certification?</td>
</tr>
<tr>
<td></td>
<td>C1.14 Which certification bodies are currently responsible for which EA artifacts?</td>
<td>C2.14 Which actors and collaboration processes will emerge for necessary certification?</td>
</tr>
<tr>
<td>Development of IT artifacts</td>
<td>C1.15 Which essential IT artifacts are used by multiple actor classes?</td>
<td>C2.15 Which IT artifacts will be created or changed by the transformation?</td>
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<tr>
<td></td>
<td>C1.16 Which platforms in the ecosystem play a central role for the collaboration between relevant actor classes?</td>
<td>C2.16 What effects will the integration of a new platform have on actor classes, their processes and the IT landscape?</td>
</tr>
<tr>
<td></td>
<td>C1.17 Which technologies are prevailing in the focal ecosystem?</td>
<td>C2.17 How do new digital trends affect the IT landscape and developed IT artifacts?</td>
</tr>
<tr>
<td>Privacy and Security</td>
<td>C1.18 Which information flows exchange personal data between which actors?</td>
<td>C2.18 Which privacy-sensitive information flows will occur due to the transformation?</td>
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<td></td>
<td>C1.19 How are interfaces secured that exchange sensitive data?</td>
<td>C2.19 Which new interfaces are responsible for exchanging sensitive data?</td>
</tr>
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<td></td>
<td>C1.20 Which security measures are essential within the EA of actor classes?</td>
<td>C2.20 Which new security measures have to be implemented in the EA of actor classes?</td>
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</table>

Table 1. Architectural Concerns on Ultra-Large Scale Digital Transformations

**Identification of actor classes**: In project management, identifying relevant actors represents a common approach. However, this task is increasingly complex for a large number of actors. For an ecosystem perspective, actor classes have to be identified that match roles of actors within a project (C1.1; C2.1). In our case study on the German eID card and De-Mail, we found out that business models and interests of actor classes were not considered sufficiently. Although enterprises could gain benefits by offering secure services based on these solutions, our interviews revealed that there was no profitable business case due to high costs. Therefore, we also suggest capturing interests and business models of actor classes (C1.2; C1.3; C2.2; C2.3).

**Transformation and collaboration of actor classes**: Modeling the as-is and to-be EA and collecting required information within a digitization project in one organization is already a challenging task. From an ecosystem perspective, EA artifacts that are used by multiple actors and are intended to be changed by a digital transformation can serve as a starting point to reflect the as-is and to-be EA of actor classes (C1.5; C2.5). For this purpose, it is essential to focus on EA artifacts that are responsible for the specific collaboration processes being affected by a project (C1.6; C1.7; C2.6; C2.7). For example, EA artifacts responsible for several collaboration processes between forwarding companies, truck drivers, terminal operators and the port authority had to be analyzed (as-is) and extended (to-be) by IoT technology in the seaport case. In the school software case, digital collaboration processes were established between teachers, parents, students and numerous schools as the developed platform enabled new ways for exchanging specific data.
Ecosystem monitoring: In the time-consuming progress of ultra-large scale digital transformations, the EA and interests of actors within an ecosystem change due to continuous influences. In our case study on the German eID card, we found out that a lack of tracking digital trends was a main reason for the non-adoptions of this solution across citizens. During the project, the introduction of smartphones increased the expectation of mobility, but the German eID card’s design was based on a separate card reader and could not be aligned without exceeding budget and time. According to our interviews, digital trends were not monitored sufficiently as the focus was on improving security. Therefore, we suggest considering concerns for monitoring trends and modeling their impact on the to-be architecture (C1.10; C1.11; C2.10; C2.11).

Legislation and certification: Digital transformations that aim to change or create whole ecosystems need to consider more regulations than most intra-organizational IT projects or even require an initiation of new laws. In addition, the development and diffusion of new IT solutions or services is often linked to necessary certification measures to verify compliance with defined requirements. Hence, an ecosystem architecture should comprise information about relevant laws and relate them to actor classes and their EA that shall be transformed by a project (C1.12; C1.13; C2.12; C2.13). While in the sector of healthcare apps numerous health laws and privacy regulations, such as the General Data Protection Regulation (GDPR), determine the design of an ecosystem’s processes and IT landscape, in our case studies on the German eID card and De-Mail we observed the emergence of sub-ecosystems for certification consisting of complex collaboration processes between certification providers, service providers and developers.

Development of IT artifacts: To develop successful and sustainable IT artifacts that are actively used by participants of an ecosystem, project managers of ultra-large scale digital transformations must consider whether these new IT artifacts fit into the existing EA of actor classes and whether they comply with actual requirements and digital trends (C1.15; C1.17; C2.15; C2.17). Especially the crucial role of platforms as key drivers of networking in many ecosystems must be taken into account (C1.16; C2.16). In the school software case, the software vendor had to analyze existing architectures in schools to ensure that the developed platform fits into these architectures. To balance costs, the platform’s minimum requirements had to be aligned with the available performance of the schools’ IT. In the seaport case, the exploration of IoT use cases led to the requirement of setting up an integrated IoT platform as a fundament for the rollout activities.

Privacy and security: As the processing of personal data is increasingly involved in IT artifacts diffused by digital transformations, an awareness of sensitive information flows between actor classes (C1.18; C2.18) and necessary security measures (C1.19; C1.20; C2.19; C2.20) within the ecosystem is becoming even more important. Especially in the context of healthcare apps and highly sensitive personal data, full transparency on data sharing with third parties is required to avoid incomplete privacy statements and to comply with regulations like the GDPR. However, in our analysis on De-Mail we found out that its closed system achieves a high level of security, but does not support a conjunction with familiar e-mail addresses and applications, which was a main reason for non-adoptions. Capturing effects on collaboration processes and the to-be EA of actors in an ecosystem can architecturally support the difficult task of balancing security and usability.

Development of the Meta-Model

Similar to EA meta-models, we used layers to structure relevant artifacts along the ecosystem architecture to reduce the overall complexity, allow a zoom-in on specific slices and provide coherence between logical relations. By combining the bottom-up approach based on stakeholder concerns (Lagerström et al. 2009) with the top-down guidance by the ecosystem modeling requirements (Benedict 2018), we derived four layers and their corresponding artifacts that are capable of illustrating relevant parts of both the ecosystem and the EA of actors within ultra-large scale digital transformations (see Figure 2). We integrated relevant components from the meta-models on EA and ecosystem architecture we described in related research to receive the artifacts and attributes we needed for answering the concerns. In the following, we briefly present the derived ecosystem architecture layers and their essential artifacts.

Domain: This top layer in the ecosystem architecture meta-model includes overarching influences and goals that affect all involved actor classes, their collaboration processes and IT landscape within a digital transformation. While domain goals on this layer describe future states of the ecosystem that are commonly sought by participating actor classes, transformation goals reflect the desires of a change in the ecosystem through a specific project. Since continuous societal, regulatory and digital influences have great impact on the course and success of a transformation project and might lead to significant changes in the behavior of actors, they should be captured as well in order to support a perceptive ecosystem monitoring.
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Actors: On this second layer, actor classes represent the central entity, as modeling single actors might be too granular for an ecosystem perspective. However, as central key players often act in ecosystems, the possibility of modeling single actors and connecting parts of their EA with the EA of other actor classes is also required. Therefore, we suggest an additional actor entity that represents individual organizations. According to Moore (1996) and Iansiti and Levien (2004), we included attributes like roles and functions for characterizing these entities. As ultra-large scale digital transformations have to consider the individual interests and business models of actors and actor classes, we also suggest capturing these on this layer.
Collaboration: This layer represents the logical organization of collaboration processes between multiple actors and actor classes. Collaboration processes play a central role in ecosystems, as they represent the key to value co-creation, knowledge sharing and general economics. To form a collaboration process, parts of business processes, services and individual activities, which take place within the EA of each actor and actor class, are combined. A collaboration process or an aggregation of multiple collaboration processes result in a service, which provides value to citizens, authorities or enterprises participating in the focal ecosystem. For regulating collaboration processes, contracts are signed between actors who assure realizing their part of progress. In ultra-large scale digital transformations, these contracts are of major relevance, as they act as a basis for transparency on relations and ensure goal-oriented cooperation between involved entities.

IT Landscape: Providing the technological basis for collaboration within an ecosystem, the IT landscape as the fourth layer contains IT artifacts that are necessary for realizing actor-specific tasks and inter-organizational data exchange. The platform entity, being often provided by a key player and representing a typical characteristic of many ecosystems today, acts as a major enabler for collaboration by connecting the IT of multiple participants. In addition, by retracing information flows of sensitive data objects along the IT landscape and collaboration layers, the architectural perspective on inter-organizational privacy and security concerns can be taken into account. As the IT artifacts on this layer are part of the EA of actors and actor classes, we could extract and aggregate them from existing EA meta-models (Winter and Fischer 2007; Aier et al. 2008; Burmeister et al. 2019).

Demonstration of the Meta-Model

Stakeholder concerns refer to one or more layers of an architectural meta-model. To derive concrete models that are capable of answering specific concerns, relevant slices of the meta-model have to be instantiated. In this process of selecting and modeling concern-oriented slices, we differ between a horizontal (one layer) and a vertical (cross section of layers) slicing. We seek to demonstrate the supporting of ultra-large scale digital transformations by our ecosystem architecture meta-model using horizontal and vertical slicing based on representative as-is and to-be concerns we derived in our case studies.

Horizontal slicing: Although most concerns we identified in the relevant architectural perspectives refer to relations across multiple layers, some concerns call for a focus on one layer. For example, by modeling necessary artifacts and attributes on the actors layer, the concern “Which functions, roles and interests do actor classes in the ecosystem have (C1.2)” can be answered. During a digital transformation, a constant overview of affected actors, their roles in the ecosystem and their main interests is essential for a designation of key drivers and a continuous alignment of progress. Another horizontal concern refers to modifying the IT landscape layer: “Which IT artifacts will be created or changed by the transformation (C2.15)” Modeling the effects of new IT artifacts that are intended to be rolled out on the existing IT landscape of different actor classes visualizes the effort for change and allows an assessment of future acceptance across end-users. We also suggest capturing platforms as a central artifact on the IT landscape, as they play a key role in many ecosystems and ultra-large scale digital transformations today.

Vertical slicing: Modeling relations between artifacts and across layers provides the possibility to answer complex architectural concerns. In our case studies, we recognized the concern “Which information systems, infrastructure components and interfaces are used for which collaboration processes (C1.7)” as a key architectural issue of understanding how socio-technical collaboration in a specific ecosystem actually works. To answer this concern, our ecosystem architecture meta-model suggests combining relevant parts of the EA of involved actors and actor classes, including business processes and services from the collaboration layer and interfaces and other IT artifacts from the IT landscape layer. In the e-government projects we analyzed, certification played an important role, leading to the need of anticipating and managing new entities: “Which actors and collaboration processes will emerge for necessary certification (C2.14)” Our meta-model allows to derive vertical slices that focus on modeling actual or future sub-ecosystems consisting of relevant actors, their processes and IT artifacts necessary for certification. Modeling entities that are part of sub-ecosystems and how these are embedded in the whole ecosystem provides transparency during an ultra-large scale digital transformation and helps to improve stakeholder management. “Which privacy-sensitive information flows will occur due to the transformation (C2.18)” is another concern of interest, as privacy and security are topics increasingly relevant in digital transformations. By relating actors and actor classes to collaboration processes, interfaces and data objects and by configuring privacy-related attributes, the ecosystem architecture meta-model enables a tracking of sensitive information flows and provides insights into security-critical artifacts and relations.
Discussion

In this paper, we developed a generalized ecosystem architecture meta-model that is intended to support different kinds of ultra-large scale digital transformations. In multiple case studies, we identified various unstructured information needs of stakeholders responsible for project management, which could have been structured and taken into account by a concern-oriented architectural thinking in the large. While Winter (2014) describes architectural thinking as a way of thinking and acting throughout an organization for increasing the impact of EAM, we argue that an architectural thinking at the ecosystem level can even provide a substantial way of managing ultra-large scale digital transformations consisting of complex socio-technical relations between multiple actors. We argue that extending the fundamental idea of EAM to an inter-organizational ecosystem perspective provides an approach to analyze a project’s complex environment, design future collaboration processes and the related IT landscape, forecast the impact of influences and prevent reasons for failure. As the insufficient impact assessment of influences and the inadequate analysis of effort for change represent major reasons for the failure of digital transformations (Alami 2016), we seek to position our ecosystem architecture meta-model as an essential instrument for an architectural thinking in the large in order to support a continuous achievement of transparency. By architecturally observing relevant aspects of interest during the course of a digitization project and capturing as-is and to-be states of the focal ecosystem, milestones can be visualized and decision-making be improved. In contrast to other ecosystem meta-models that have a specific scope (Feltus et al. 2017; Oliveira et al. 2018), we argue that our meta-model is capable of reflecting different types of ecosystems through its generalized artifacts. In addition, we argue that it supports both the analysis and design of ultra-large scale digital transformations, as it allows to architecturally address relevant information needs through its orientation on layers, its capability to visualize the impact of external influences and its integration of specific parts of the actors’ EA that are necessary for collaboration. However, depending on a project’s purpose and scope, initiators or architects might adjust our proposed artifacts and attributes according to their specific needs, as our meta-model represents a very abstract level. Furthermore, we can imagine setting up an ecosystem architecture management in these long-term projects of large scale, with tasks similar to EAM, like standardization, innovation integration and business IT alignment (Saat et al. 2016). We see the six architectural perspectives as a starting point for these extended tasks. For example, while the EAM considers the impact of external influences within the borders of one organization, this has to be done for multiple actors by an ecosystem monitoring. Moreover, the EAM realizes the transformation from as-is towards to-be for one actor, whereas ultra-large scale digital transformations have to consider changes in the EA of multiple actors. To exactly define these extended tasks at the ecosystem level, more basic research and empirical insights are required.

The results of this paper are not without limitations. First, we used four case studies as an empirical basis to derive representative stakeholder concerns. Even though we sought to generalize our results, additional case studies on ultra-large scale digital transformations might have revealed other architectural perspectives and concerns of major interest. Second, as we developed the meta-model based on these concerns, only selected artifacts and attributes of a comprehensive ecosystem architecture meta-model could be demonstrated. Third, we just roughly discussed the idea of an architectural thinking in the large in this paper. Future research is necessary to complement the architectural perspectives and illustrate the use of the ecosystem architecture meta-model in practice. In a next step, we therefore seek to evaluate and refine the meta-model by applying it to different kinds of complex digitization projects. Moreover, the idea of an architectural thinking in the large requires concrete definitions, theory-based concepts and empirical evidence.

Conclusion

This paper dealt with the research question: Which layers, elements and relations need to be included in an ecosystem architecture meta-model for addressing stakeholder concerns in ultra-large scale digital transformations? By conducting case studies on projects in different types of ecosystems, we revealed major concerns of responsible stakeholders and categorized them into six architectural perspectives. For supporting these concerns in future projects, we developed an ecosystem architecture meta-model by combining and extending elements of EA and ecosystem meta-models from the literature. Our results contribute to research and practice alike. For academics, they provide implications to the relatively unexplored field of extending the idea of EAM to an ecosystem perspective (Drews and Schirmer 2014). In addition, the developed meta-model addresses the demanded coverage of holistic ecosystem complexity through its generalization (Weber and Hine 2015), whereas most other ecosystem meta-models provide
depth of coverage by focusing on selected aspects. Furthermore, our results represent a first step towards an architectural thinking (Winter 2014) in the large. We argue that an architectural thinking that combines aspects from both the EA and ecosystems can help to capture and recognize the increasing complexity within digital transformations. For practice, the architectural perspectives and the meta-model provide guidance for receiving transparency on ecosystems and thereby support the realization of ultra-large scale digital transformations. Above all, the idea of an architectural thinking based on ecosystems shall influence future projects and help to avoid failure-reasons such as those exemplified by our case studies.

REFERENCES